

"SOME SCIENTIFIC AMERICANS"

6. "Is Science Human?"

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OPENING ANNOUNCEMENT:

This is the BBC Third Programme.

"Some Scientific Americans".

We're opening this evening with the sixth broadcast in this series. It has been compiled and is narrated by Gerald Leach from conversations he recorded in America earlier this year. Tonight's programme deals with some popular fears and misconceptions about science. It poses the question "Is Science Human?".

Reel 1

CUE IN: "I know of no basis on which to reach a conclusion....

CUE OUT: ...of the public generally".

Reel 2

CUE IN: "Now here, in contrast, are the views of Joshua....

CUE OUT: ...nothing new in the world.

CLOSING ANNOUNCEMENT:

That recorded programme, the sixth in the series of "Some Scientific Americans", was compiled and narrated by Gerald Leach. It was produced by David Edge.

The speakers you heard were: Joshua Lederberg, Professor of Genetics at Stanford University, Linus Pauling, Research Professor at the Center for the Study of Democratic Institutions, George Kistiakowsky, Professor of Chemistry at Harvard University, Jonas Salk, Director of the Salk Institute for Biological Studies and Robert Oppenheimer, Director of the Princeton Institute for Advanced Studies.

In next month's programme in this series, you can hear Professor Lederberg discuss further the social and ethical implications of the "biological explosion".

That's in the Third Programme on 16th January at ten minutes past eight.

14.12.65

DAVID EDGE

"SOME SCIENTIFIC AMERICANS"

6. "Is Science Human?"

LEDERBERG: "I know of no basis on which to reach a conclusion contrary to the assertion that a machine which has acquired the human programme is a man. In fact, man is a machine which has received, and can compute, the type of programme which we now customarily attribute to the human being."

LEACH: True or false, that is the kind of scientific remark that tends to alarm people. It was made by Dr. Joshua Lederberg, the Nobel prize-winning geneticist who now directs the laboratory of Molecular Medicine at Stanford University, in California. We shall hear his statement again in its proper context, later in this programme. But I open with it because it typifies a trend in scientific thinking that puts up walls of misunderstanding - and even of fear - between scientists and the general public. Take another example. Here is Professor Linus Pauling, Nobel prize-winner for chemistry and for peace, talking about the brain as a machine.

PAULING: Our experience shows that we can understand thinking, the functioning of the brain, or we can understand mental processes - the mind, in terms of the molecules that make up the brain. I would say I believe that not only physical actions, but also psychic phenomena are the result of the interactions of the molecules with one another, the molecules that constitute the human body.

LEACH: It's fairly certain in the next few years that psychologists or human scientists as a whole will show that such characteristics of personality - as love, compassion and so forth have what we might call a mechanistic origin. Does this worry you?

PAULING: No. It doesn't worry me at all, I have become so used to getting an understanding of phenomena in the world in terms of molecules and radiant energy that the extension of this to living organisms and to human beings, even involving what we call the mind does not cause me any trouble at all. And I believe that as time goes on we shall understand more and more about the nature of man in terms of his molecular structure and that there will always be then questions remaining to be answered - I myself I think probably shall preserve to the end of my life the belief that more and more of these questions will be answered in a way that I can understand in terms of molecules and their interaction with the rest of the world.

LEACH: This kind of faith is very common amongst scientists. Now should we welcome it, applaud it - this confidence that we can know and explain everything (even the brain, mind, love and compassion) with its implication that we must know because knowing will benefit us?

LEACH(CONT). Or should we fear it? Is it perhaps, not confidence but an excess of arrogance or pride, and a threat to some of our most deeply held human values? And in adopting these attitudes, do scientists abandon something that is essentially human? This programme brings together some conversations that touch on these questions. I hope that they will throw some light on the human values of scientists and of science and that they will also reveal how scientists react to the chief public fears about science. The first fear that we look at is of a take-over by the machine. Will man be kicked yet again from his dominant place in the Universe and be turned into a partner - even a slave - to the machine - and especially, of course, to the computer. I talked about this with Dr. Lederberg. We discussed how far the man-computer partnership might go - and should go. At one point I asked him whether he really thought that we would use computers to do our household arithmetic for us - even our shopping bills and tax forms.

LEDERBERG: Oh I think there's no question about that, - I'm not sure we'll have to work out our tax forms, all this will be done for us and we need only exercise a very general supervisory programme implemented on our behalf.

LEACH: But as a result man loses the capacity to do arithmetic.

LEDERBERG: That could be unfortunate and of course if he becomes completely slothful and lets the computer do every one of his jobs for him which might happen at certain levels, it would be extremely unfortunate. However - to take its place - the energetic man will learn the programming of his computers to solve the problems that he has. He will also learn how to invent problems which will present interesting challenges to the computer.

LEACH: I mean this seriously because this is analogous to what is happening in medicine after all where the advance of medicine is allowing more and more genetically unfit people to survive, I think of the diabetic now can survive through to reproductive -

LEDERBERG: But was the diabetic genetically unfit? He was unfit when insulin was not available -

LEACH: Sure.

LEDERBERG: - to tide him over.

LEACH: But he - he now becomes more reliant on our present culture.

LEDERBERG: Well that's absolutely true but I think you're also reliant on your clothing and your shelter and the kind of food that you've been accustomed to eat.

LEACH: Yes, but he becomes reliant on a culture, on the most advanced culture - what you're suggesting is now the computer is - doesn't allow someone to go to a backward part of the world, he's then lost, he then hasn't got his cultural props with him, just as the diabetic can't go anywhere where he can't get a supply of insulin. The man is more limited in this respect.

LEDERBERG: He is more limited. He has to have a more precisely defined environment in which to operate, in order to take advantage of the capabilities that that environment offers. I'm not the least bit alarmed by that specialisation, especially insofar as it doesn't impinge on his ultimate capacity to undergo biological adaptations. What would alarm me most of all would be premature decisions that might become irreversible because of the loss for example of certain constellations of genes. I feel that the lesson that evolution teaches us about ethics, rather contrary to the social Darwinism of some decades ago, is the perfectibility of man, that man is capable of considerable further evolution as he has evolved in the past, that this will occur both in the psychological and ethical as well as in the biological sphere and we ought to recognise that we are but transitional stages in the evolutionary process. And that by that very token we ought to be very suspicious of the judgement that we as imperfect steps in this process make, that might prejudice the overall development of the entire story. Though I'm very willing to encourage all sorts of specialisations in human capability and with regard to the conditions under which man must operate, I would be extremely cautious about the kind of decision that would foreclose the opportunity to choose a variety of directions in the future when the utility of those directions becomes apparent to a posterity that is more able than we are.

LEACH: There's a second fear that embraces this "take over fear" and that is of the sheer power of science and technology. There they are, racing away into the future, adopting their own rules and values as they go, while our social and political institutions struggle to catch up. And we wonder, sometimes, whether they aren't often racing off in the wrong directions - failing to solve urgent problems we want them to solve, or raising all kinds of new problems we cannot cope with. I talked about this with one of the most eminent of American scientist-politicians, Dr. George Kistiakowsky, of Harvard University. I put it to him, bluntly, that the public looked on scientists as magicians who can solve any problem - and that science often seemed to tackle the wrong problems - wrong, that is, by social and human values.

KISTIAKOWSKY: Oh, but that's a completely wrong approach; I'm afraid this is a non-scientist's approach to the situation. I think the statement should be very different. That's as science - or rather, as the practical utilisation of science solves certain problems of society, it inevitably creates new ones. The important thing and I think this is probably where I stand at one pole of the spectrum of opinions, my contention is that with very few exceptions, the net result of solving a given problem and creating a new one is of benefit to society, there are some people, I think, for instance, Mr. Hutchins, the former President of the University of Chicago, is near the other pole, he says science is horrible, it only causes trouble. Well, I just don't believe it, I think I could build-up a very good case that that is not so.

LEACH: But there are still many people who - you know - have a deep mistrust of science, they look on you as a kind of new priesthood dedicated to the machine. You know, while this exists, don't you think that science is in some kind of jeopardy?

KISTIAKOWSKY: Well, this does require some public education, I think - I think that, of course, when people see scientists as magicians manipulating some very dangerous levers in a hidden machinery, that is a very harmful approach. To me a scientist is simply a man who has an intellectual drive to know. At least the real scientist; he advances man's knowledge of the world and of man as an element in that world. Other people with a flair for the practical explore the possibility of using this knowledge for practical purposes, most of the time these purposes are beneficial to society, not always, I grant you. And that is where the danger lies, but I think the people who are resentful of science should worry not about the pure science, the advance of knowledge, but about restraints on those who would use new knowledge for evil purposes.

LEACH: And this is much more a political question?

KISTIAKOWSKY: Yes.

LEACH: But looking ahead, do you see any areas where the people who fear science can be justified, I - I look at some possible developments in biology, I know it isn't your field but as a chemist you're fairly close to it in terms of genetic manipulation and so forth? But you know there is a body of opinion which says cry "Halt". Shall we think about what we should be doing rather than what we can do?

KISTIAKOWSKY: Well, I don't know, I think there is of course the possibility of very evil applications, a situation may develop which will not be very different from that which developed in physics upon the development of the atom bomb.

KISTIAKOWSKY (CONT).: Until then physicists were actually much more removed from practical life than were, for instance, the chemists. And the two groups of scientists also politically were quite different in all this - physicists were generally much more to the left politically than the chemists; chemists had usually good contacts with industry and so forth. The strong sense of guilt which Oppenheimer has spoken about this has been characteristic of the physicists' community because the development of the atom bomb suddenly was sprung on them and overnight changed their relation to practical life.

LEACH: And they weren't ready for this?

KISTIAKOWSKY: Yes, they weren't ready for it. I think that we're dealing in biology with very much the same situation. The fraction of biologists who are for instance interested in public affairs and are active in the government councils and so forth, I think, is very much lower than it is for physicists and even for chemists when and if the present incredibly exciting research in, say, molecular biology leads to practical possibilities of modifying genetic inheritance and therefore doing it for both good and evil purposes. I think the biological community may all of a sudden wake up with a start and start acquiring feelings of guilt, but hopefully before then they will be sufficiently educated that they could take a mature attitude and try to influence public policy so that the results of their research would be used for good rather than evil purposes.

LEACH: The explosive pace of the biological sciences will, undoubtedly, raise many difficult personal and social issues. How, for example, should we regard abortion when doctors can detect with certainty that a foetus is severely deformed? Dr. Lederberg and I discussed a number of problems like this, and he emphasised just how deeply they will penetrate, and how unfitted we are to cope with them. I had asked him, personally, whether he thought the decision to have a child should be entirely up to parents or whether society should also have some say.

LEDERBERG: Well I don't feel that there is any element in existing society that I would at present time trust to have sufficient knowledge of human biology, or wisdom concerning the purposes of human existence if you want to entrust such a decision to on a large scale. I think implicit decisions along these lines will have to be made by society as a whole. Questions of this sort are likely to become virtually commonplace as our knowledge of the biology of reproduction, the biology of human development and the biology of life and the biology of death, become deeper and these will not be merely the occasional perplexities that will arise every now and then but will become the daily concern of almost every aspect of our living.

LEACH: Decisions on all this will have to be made both privately and collectively, and we have hardly begun to thrash out our basic approach to the. When we do, Lederberg stressed, we must watch the danger of giving short-term answers and of taking extreme views about the value of human life.

LEDERBERG: I think we face a very real danger in making our decisions collectively so closely coupled to the immediate circumstances of our existence as a species that they overlook the long-range requirements for flexibility, for the chances of discovery of other approaches to the nature of life, and for the exercise of talent for which there is not now a need.

LEACH: But one can take perhaps a specific example. I think of a mongol child, something of this sort. Do you feel that the answer is to simply tell people what the statistical chances are and leave it up to them?

LEDERBERG: I think there's a point I really must make very emphatically. Regardless of how mechanistic one's views are concerning the nature of the human organism, and I would count myself as a reasonably profound mechanist, I think that we must produce and protect what is at least a myth of human dignity if our society is to continue to function in an effective fashion, if there's to be any reasonable expression of the most creative aspects of human capability. I think that questions like the desirability of preventing the survival, or of not permitting the survival of mongols, must be thought of not only in terms of the penalties which an individual family or society as a whole may suffer from having to maintain such unfortunate individuals, but also the penalty which attaches to the maintenance of - what I called a myth - of human dignity when intemperate interference with human survival is practised. We must find some way in which we can steer between the preposterous requirement of maintaining every conceivable kind of monster or tissue fragment or other product ultimately in some fashion related to human existence, and on the other hand a kind of disregard for human individuality which could result in the extermination of the larger part of the ultimate human potentiality.

LEACH: Scientific knowledge is here exposing basic moral issues - but you can hear more of this from Lederberg next month in another interview in this series. This challenge to our human values from bio-medical science arises from its growing power to understand and control the most intimate living processes, including human ones. And this is only possible because these processes, including the human body, are themselves understandable. In a sense, we are machine-like, predictable. In many ways we welcome this: knowing about the human machine leads to all the advances of modern medicine and surgery.

LEACH (CONT.): But it also leads to the third fear - an intellectual fear - that man seems to be somehow diminished by being explicable. Dr. Jonas Salk, discoverer of the famous polio vaccine, is now director of the Salk Institute for Biological Studies, in California. I asked him how far he took the idea that living matter is basically no different from dead matter. If the cell is a little machine, understandable and manipulable, is the whole animal and the brain also machine-like?

SALK: Well I wouldn't quite agree with the statement as you've put it because it could easily be misunderstood that there is no difference between living and dead matter. On the fact of it our senses tell us there is a difference. What we do not know is the nature of this difference. It's perfectly clear that as organisms increase in complexity there are aspects that we don't quite understand, the explanation of which doesn't immediately meet the eye and certainly man and his mind is in the realm.

LEACH: Do you believe that there's a mechanistic explanation for the whole of man?

SALK: That question has many parts. I think that we have to approach the component parts as we would any complex problem. What you have in mind when you ask the question is there a mechanistic explanation, and what those who listen to you might think, may not be exactly the same thing. Understanding that there are molecular forces that are involved, certainly at the cellular level, and understanding further that the interaction between two cells involve substantive things, such as molecular elements, makes it appear that as one reaches further out into organismic relationships, the establishment of tissues and organs, and the relationship between organs, the whole becomes greater than the sum of the parts. Now what this excess is due to beyond the sum of the parts now represents a new level of understanding, both at the molecular level you might say and in terms of man's comprehension. We know from our own sense that either light or sound have an effect upon us. The translation of these stimuli to produce the effects that are produced upon the brain and upon man's emotions clearly requires a more precise comprehension than now exists. How would I go about trying to arrive at that kind of understanding? I think that it's clear that we have to build from the bottom - that we have to now think, not in terms of sociology and psychology and anthropology - we have to now think in terms of neurobiology, psycho-biology, social biology. We have to begin to develop the biological basis for understanding these phenomena that we look upon as being strictly human. As our understanding increases in this respect, we will soon find that there are sets of ideas that are highly

SALK (CONT): useful for understanding far more complex phenomena that represent in a way the results of evolution, of structure-function relationships that existed at the most elementary level and we might even be able to trace these back to the elementary particles.

LEACH: What happens when an organism becomes more complex? This is the extra something that's more than the parts.

SALK: Yes. Something new does appear in a way. You have not only the thing in itself in relation to an external environment, but you have the development of what you might call an internal environment and this is essentially what happens with increasing complexity that a thing has an environment, and other elements - other things in its environment become an environment for it which it becomes the environment. Now it's clear that this kind of interaction now produces new sets of forces. We know this is true, not only at the molecular level but we know that it's true at the level of people.

LEACH: And also to a growing extent, of computers. A computer has an internal sense system, it can tap its own memory, it has external senses and so forth.

SALK: Yes, and there are some who have the kinds of minds that can encompass these similarities, can understand them, and therefore develop themselves in the direction of further simplification, further understanding and in a way a kind of wisdom that transcends the knowledge of the individual facts.

LEACH: You don't believe that sociology and the so-called human sciences can, in fact, find laws of interaction between people - social groups.

SALK: I think they can.

LEACH: But you think they must also come from the bottom.

SALK: Must come from the bottom up. I think the time is now long past for us to look to mythologic figures, to look to hypotheses that derive merely from making observations in some narrow realm of human behaviour at a given point of time for the purpose of deducing the laws that govern human interaction and social interactions; I think we have to look in the other direction now.

LEACH: We then went on to talk about how this kind of biological thinking might spread out to influence the rest of our culture and philosophy.

SALK: I think that as our understanding of biology increases it will inevitably have an effect upon our way of thought in all areas of human life. As we understand more about the phenomenon of immunologic tolerance and intolerance, I think we'll understand more about the phenomenon of tolerance and intolerance at the social and the cultural level.

SALK (CONT.): It's this kind of interaction, this kind of influence that I see developing. We tend to be anthropomorphic and explain molecular phenomena in human terms. I don't think we want to short-change the humanist, nor do we want to discard the wisdom of the past and the observations of the past. This would be a great mistake because you must remember that there were men who lived before who had nothing to do but think about that which they observed in purely human terms. The number of truths that one finds in Shakespeare, one finds in the stories of the Bible, or in the formulations and developments of religions around the world since the beginning of time, probably come as close to representing in terms that I hope scientists will soon begin to accept in fact themselves will develop the analogues for - let's say the story of Job that would be as readily acceptable and understandable to them as it is to those who understand these stories and accept them literally.

LEACH: These other truths, the humanistic truths, are those that most of us know - we experience them ourselves. We can get inside them, whereas we can't get inside the biological approach to man.

SALK: That's right.

LEACH: You think these can meet.

SALK: They can, because they meet in some of us and therefore they can meet in all of us.

LEACH: This is accepted by yourself and others as a very obviously very basic philosophy. To most of the world, I think, looking at the kind of work you're doing, there is quite a different feeling. There is a sense of fear, a sense of hubris that you are explaining man as a machine.

SALK: That's why I handled as I did your question as to whether there is a mechanistic explanation for all of this. That's looking at it from too limited and narrow and defined a point of view. I think when we use words we sometimes destroy the essence of the meaning of things. To state at the outset that one is going to explain man mechanistically tends to limit the number of hypotheses that we are will to develop. I would rather say that we will arrive at an understanding of man retrospectively as we develop our understanding of the nature of living systems. I can merely pursue that which seems to make sense to me. I can continue to develop the ideas, or listen to the ideas, that occur within myself as I find myself reacting as a human being to the things that I learn and that I can know. My expectation is that ideas such as this will inevitably spread. I see a great desire and hunger for ideas of this kind amongst young people. The teenagers and those early in their college careers are the ones that understand these ideas much more readily and don't fight it and have almost a passion for the feeling that this gives them.

SALK (CONT.): To experience more and more of this, to want to participate in the further development of these ideas. And I see more and more need of young people who are drawn to science also to include as part of their lives what we would normally call humanistic and aesthetic activities, the arts.

LEACH: But this will take a generation or so to....

SALK: In exactly the same way as a generation is required for the establishment of any new paradigm.

LEACH: Do you think there's a fear that in the meantime, before this generation is up, that the biologists will do certain things which will be severely misunderstood. I think, for example, of the creation of life which is on **the cards**.

SALK: That statement strikes awfully close to people and to where they live, so to speak. And yet to me it doesn't mean very much in practical terms. Certainly we might understand more about the molecular basis for living material and we may understand eventually how to put molecules together, that will not only have the capacity to code and decode but have other of the properties of life. We are so far removed from being able to compete with the millions of years of evolution that this sort of idea doesn't instil me with any fear, nor any concern. Nor do I think that it should instil fear or concern in the minds of the public generally.

LEACH: Now here, in contrast, are the views of Joshua Lederberg - whome you've heard describe himself as "a reasonably profound mechanist" - on the same topics. I asked him if he foresaw any serious upset to Man, to human values if biologists create a totally artificial form of life, and so remove some of its mysteries.

LEDERBERG: I don't really see why it should. If so, he ought to be upset already since I think we already understand well enough the specifications of living organism that there are no profound intellectual barriers to its accomplishment. It seems to me that the creation of life at the present time is very much more a technological than a scientific problem. For that reason we may not bother to do it. We may discover that the investment required to emulate what creation has already accomplished isn't worth what it gives you and that it's sufficient to understand the principles of the mechanism by which such a complex set of machines is brought about rather than to endeavour to recreate them by explicit synthesis from the ground up and while I believe some efforts are likely to be made in this direction I think there will be much more emphasis placed on understanding the principles by which existing life operates and in moulding the direction of its flow rather than attempting more as a tour de force than perhaps an independent intellectual achievement to create what might by convention be regarded as a living organism.

LEDERBERG (CONT.): The mysteries, though I think pertain not only to life in general and the surrounds of the universe but also to the very nature of man himself and as we approach a deeper understanding of the biological mechanisms of which he is fabricated, as we begin to attack even such questions as intelligence and resources of individual personality, we may wonder whether any mystery will be left whatsoever. I'd like to pose that there still is one and that is the direction in which man is ultimately going. This is not so much the mystery of the individual, as it is of the species, what that ultimate end and in that sense the ultimate purpose of his existence will have been.

LEACH: What bearing does the enormous explosion of molecular biology in the last decade have on the view of the nature of man?

LEDERBERG: Well the conception that man is a chemical machine is, of course, by no means a novel one. But there have been any number of mysteries concerned with some of the most elementary aspects of biological function which as long as they could not be framed in explicit physical and chemical terms could certainly be the refuges for a variety of types of vitalistic thinking. This I think was particularly true of the nature of the gene and the manner of its replication. It is not very many years ago when this was regarded as a phenomenon of its own kind, possibly not even susceptible to the ordinary rules of physics and chemistry, and yet with astonishing speed the crucial issues that gene replication have presented have become dissipated under the impact of what is, after all, quite simple and quite straightforward physics and chemistry.

LEACH: And one can carry this right back to the origin of life as well?

LEDERBERG: Well we have at least a framework in which the origin of life can be made to appear a plausible event, as in a sense a side issue in the evolution of a planet, although it eventually comes to be one of the main issues directing the course of the history of that planet. Again, there was a certain myopia with respect to the ease with which reasonably elementary chemical principles could be adduced to build a system of hypotheses, many of which have been explicitly verified, in which certain steps in these continuous origins of life could be understood. Now this is still a far cry from the actual creation of life in the laboratory or in the test tube, but I think it's fair to say that there are no fundamental issues left at the present time - that is to say biology does not now see any area in which it appears to be necessary or desirable to evoke principles different from those that would be necessary to describe other kinds of chemical machine in order to describe the operation of living organisms.

LEDERBERG (CONT.): In other words, the creation of life may be regarded as a problem not by itself worth solving, because we will have achieved a sufficient solidity on an intellectual basis of the principles on which it could be accomplished, that we would be in no doubt whatsoever that at the cost of some X-trillion of dollars we could in fact accomplish it. To merely copy what creation has already produced seems to me not in itself a very important challenge. One can understand the operation of a printing press without actually repeating the detail of its having printed some particular encyclopedia.

LEACH: Do you take this mechanistic view of man to the ultimate extreme? I mean do you include the brain? Learning processes and so forth?

LEDERBERG: Well properly speaking I should say that this is itself a subject for investigation and that time will surely tell, and no amount of argument on my part is going to decide. But many flat assertions in this field are probably preposterous. There has simply been so little chemistry done on the brain that we don't know how to frame the kind of hard questions whose answer would be relevant to this. But for my own part I would certainly proceed with my research on the premiss that the brain, is a mechanism quite comparable to that of other machines in principle although perhaps of a very high order of complexity.

LEACH: The implication is that if man is a machine he can therefore be programmed. That in principle man could be programmed onto a machine.

LEDERBERG: Well I might make an even stronger statement. I know of no basis on which to reach a conclusion contrary to the assertion that a machine which has acquired the human programme is a man. In fact man is a machine which has received and can compute the type of programme which we now customarily attribute to the human being. This is as much to say that the essential quality of man is not the details of the machine, his heart, lungs, liver, even in a sense his brain, but the programme which is implemented with this use of this particular hard-ware and which might conceivably be implemented with other types of mechanical devices. The programme is the sum total of the behaviour, the social interactions, the intellectual and artistic experiences, and the total accumulation of the cultural tradition by which man is most uniquely distinguished from all forms of creation.

LEACH: How useful is such a viewpoint?

LEDERBERG: Well it certainly is a suitable conversation piece to start an argument in almost any group of people of varied backgrounds. It may be also appropriate to attempt to detach living man from an excessive preoccupation with his own material body, which

LEDERBERG (CONT): is after all something he shares with all the rest of the animal kingdom, and on which he could place no pretensions of uniqueness, to attempt to find some rational basis on which he can make some very hard decisions with respect to his treatment of other human beings; in order to do which he has to have some reasonable basis for deciding on their humanity or not. And in order to make the fullest possible exploitation of the opportunities that man is building for himself in the construction of artificial devices which programmes even better than those which he has received through the process of biological evolution.

LEACH: But does it really help man formulate something which he obviously must formulate pretty soon, which is a social ethic which regards individual personality, individual dignity, as being all important?

LEDERBERG: I'm rather pleased that you brought that up because most discussions of mechanistic biology, at least in this country, tend to arouse some reaction of demonism towards the speaker, that there is some attempt to deprive man of his individual dignity, as if the question of the mechanical basis on which he implements his functions is of any consequence to such a discussion. I'm not sure that in the present state of the development of the species, or if I must speak only for myself, from my own intellectual development, that I feel able to give final answers to problems of this kind. I do feel that there is at least a pragmatic basis for the thought that the democratic ideal is an absolutely essential basis if we are to preserve the maximum flexibility of opportunity for a wiser posterity and how to dispose of man's future than we may know ourselves.

LEACH: Science clearly has a large part to play in material progress and also in the evolution of ideas and of human values. But this leads to the fourth fear - that the process of science itself is, if not actually inhuman, then at least in conflict with human values. That it has little of positive human value to offer. We'll be looking at this for the rest of the programme; and first with Dr. Salk. I put it to him that the public mistrust of scientific values had increased enormously since the physicists had made the Bomb. Now that biologists are gaining great practical powers for good or evil, was he concerned with feeding human values into biology.

SALK: I think that the depreciation of human values comes from the way in which science is used by humans. Humans as a class have two sets of values. Those that are constructive and those that are destructive. Scientists are no different from other humans in this regard. Some of them are motivated constructively and some are motivated destructively. Some, in their destructiveness, or (psychologically speaking now), may prove to be extraordinarily good

SALK, (CONT.): scientist in the sense that they try to take apart the living cell, the molecules so to speak, to understand more and more about them. Then there are others who tend to synthesise - and put things together. We have two kinds of enzymes - those that degrade in the sense of dividing into sub-units and those that tend to synthesise - I think we will have to live, perhaps for all time, with different sets of values. Now what you are really asking, and what I keep asking myself, is can we sufficiently shift the balance of human values so that not scientists alone, but the public at large have what I like to think of as more humane values. What are these values? How do they manifest themselves? Well there are all sorts of words that we can use, including words such as compassion, but when man is sufficiently pressed, when he is sufficiently deprived, either of food or of love, of pride, he will behave as a destructive animal. He will defend himself, he will attempt to destroy others. These are simple observations which we can all make, and we can find analogues in the jungle, we can find analogues in the control systems within cells. Some molecules turn a cell on and some turn a cell off. These are simple thoughts. We have to think about the human problem, it seems to me, not only at the human level but at all levels. And try to integrate our thinking in this way. And when we do we may then be able to exercise conscious control upon the development of new human beings so that parents, if they can influence their children to be dominantly constructive if you will and therefore have human values that all recognise as human and desirable. This I think will shift the character and the quality of the human race.

LEACH: One scientist who has perhaps thought more deeply, and written more lucidly, than any other on the subject of science and human values is Dr. Robert Oppenheimer, now director of the Princeton Institute for Advanced Studies. It was there that we talked - and I asked him, not whether human values were lacking in science, but what positive human values science had to offer mankind.

OPPENHEIMER: I suppose the most important content of science is that one finds out all the time that one was wrong. The certitudes one reaches are really pretty certain for anything in human life. But the one thing that is in a sense irreversible is that one doesn't keep on making the same mistakes, one makes new ones. And the experience of scientific discovery, whether you make it yourself, or what is of course inevitably more common, you learn it from someone else - is that you have not got it straight. You had made an error - either an error in how you did things, in the laboratory or - very much more probably - in how you thought about things. Now this experience seems to me very useful one for life in general, and it is the one thing that marks off science, let us say, from drama.

OPPENHEIMER (CONT).: Drama is very much more accessible to people, it's very much more universal in its appeal: it touches aspects of the human predicament which science hasn't and probably won't touch, but it does not involve a useful irreversible correction of error. This does not always make people the least bit modest. I have been reading a bit about Galileo, whose fourth centenary this is; and he was - you might say - to some extent patient, but very fervent in pointing out the errors which he was trying to correct, and insisting that people recognise them. Bohr was always very quiet-voiced and unaggressive in manner, in speech, in spirit - but he spent the last thirty years of his life insisting on the errors that had been made earlier, and on the fact that something new had been learned, and that it was important that everyone recognise this. And I believe that the double quality which you find very markedly in Galileo, very much more muted in Bohr - of having found out how wrong people had always been, and the double quality of pride in this achievement, and the humility in the face of the folly of man is, is one of the things that does characterise all parts of science, even, what the Germans call geisteswissenschaft even the study of history, the study of man's experiences. And I believe that - although this spirit is a very prominent feature in the great religions, and is to be found in many who have almost no scientific background, but who to use a big word carefully, are great humanists, science is a very rich source of it, and I've always felt that this was one of the reasons why science had important contributions to make to culture quite apart from its delights, and quite apart from its obvious great utility.

LEACH: Later we touched on the question of man as a machine, a mechanism. I asked Dr. Oppenheimer whether he was at all troubled by our growing ability to draw up the detailed blueprints of ourselves.

OPPENHEIMER: I would think that we were over the hump insofar as we're likely to need to get over the hump, and that the idea that man is a part of nature, but that there are many problems that are not helped by discussing him in that light, was a very important one; it's a very elementary, primitive and old example of complementarity; and if in talking about how to train a cat, how to help a child, we have to go back to the behaviour of the particles of which these organisms are constructed - we would certainly never have any wisdom, and be totally unable to act - I would think the further elucidation of what special properties of matter were involved in the various functions of life was one of the most exciting things the decades ahead held in store. But the antimony "Are we a part of Nature?" - "Are we just a part of Nature?" - I think we've had to face that, and I do

OPPENHEIMER (CONT.): not believe it will be sharpened by knowing a great deal more about the specific and beautiful arrangements in nature which make life possible.

LEACH: This is what one says in 1965 but the biologists that I've been talking to are very firmly convinced; and see no reason why in fifteen or twenty years - who knows? - this kind of explanation will have spread from the toes up to the head, as it were, and, along with the finding of psychologists, what one thinks of as consciousness and personality will be pinned down rather like your elementary particles, and that one will have a much more mechanistic explanation of, you know, the most private area of behaviour.

OPPENHEIMER: Well, I think that's undoubtedly true. On the other hand, another lesson that one daily learns in the sciences is that explanations tend to be partial, and they tend to be bought at the expense of a radical simplification and a radical impoverishment of the potential experiences, and I think that with great respect for most of the biologists you have in mind, and with great interest, but a more limited confidence in most of the psychologists, that they may be a little simple in what they are foreseeing - not in how much will be learned, but in the fact that this will alter the essential inherent ignorance, which is an essential price of any knowledge at all.

LEACH: You feel that we're in fact expanding into larger and larger areas of ignorance, covering more ground in terms of knowledge....

OPPENHEIMER: Well, I think that any structured experience always limits - the structure is made by that - and I think it's stupid to say our ignorance is growing. Our ability to formulate it of course is a measure of what we've learned, and so it is growing.

LEACH: One reason why many non-scientists cannot appreciate the human values of science may be because the ideas of science and of the arts or humanities call for quite different kinds of approval, or judgement. I mean by this that scientific ideas are judged by the approval of nature - they have to check with actual repeatable experience - and in this process human approval, social approval, plays no role at all. But in the humanities, in drama say, there need be no check with the public facts of experience. Fantasies can be given a full and free reign, but these do fulfill human needs. I put it to Dr. Oppenheimer - may I say with some trepidation - that it was this that did much to split the two cultures (if there are only two).

OPPENHEIMER: I don't know that it's split between two cultures because it seems to me that in fact there's a good deal of interpenetration the same man appreciating both. It is perhaps so that the notion and nature of verifiability in the sciences and therefore in very large measure - the use of the word "truth" is radically different. I mean it's incredibly common to say, to hear, to write, to think "how true", when what you've done is read a poem, or look at a portrait, but it isn't the same meaning of the word and it could cause some confusion. There are a lot of things that a work of art does, which have some analogies in great works of science. And it's important both that they be recognised and that their partial but I believe ineluctable presence in the sciences should also be recognised. There is the question of truth and there is of course the question of largeness. There are small truths and big truths in sciences but there is also a question which is much closer to what you find in the arts and that is the thematic question, what is worth talking about? What angle is worth looking at? What connections are worth bearing in mind? And if you look at the vocabulary and the mathematical notation of the sciences you see that these thematic elements are not as trivial as the positivist's description of science would make out.

LEACH: How do you answer the many critics of science - I think maybe some of them are ignorant of what science really is, and I think they're probably talking about technology rather than science, who feel very strongly that science should be positively direct by society, so that it becomes more - and I put this in quotes - "humane"?

OPPENHEIMER: Well I think obviously that the uses that are made of knowledge, and that often includes ancilliary knowledge which is necessary in order to use something that's been found out, these are social acts in some contexts - they may be social acts of small entrepreneurs, or they may be acts of an international organisation and whether this is done well or badly, it has to be done. No-one can make the decision to make jet automobiles except automobile manufacturers, or would-be automobile manufacturers. It cannot be done by some lover of jets. I think it's also quite appropriate through patronage, private and governmental to say this is an area in which more knowledge would be of the very greatest use to man. We don't know what we'd do with it, but we know that if we had more knowledge, we'd have greater freedom of action. And I think that it's a completely natural and common thing that men respond to such patronage and to such encouragement. What you can't do is tell the scientist what the scientist can do, and that is, in the end, as far as understudying nature is concerned, the determining and the key role.

LEACH: Finally, I asked Dr. Oppenheimer whether, in the education of the rising generation, he had any fears about science and human values. And, indeed, he had.

OPPENHEIMER: The experience of science, the experience of finding out how wrong one was, may get lost and this is I believe a very common preoccupation of my colleagues that we have to have a living science, as well as the panorama of - it's not actually a landscape but a sort of a network of what things have been found out. But in the course of sketching the panorama which is something like a road map for people that want to know a little bit about what's known in the world, there has to be something which is complementary to that and that is the intimate experience of the discovery of error, and this should not just be an error which is disobeying a rule but it should be an error that the rule was wrong. This I think we ought to try to do, and we ought to try to make it as widespread as at all possible. It's very hard to catch an older generation which was dealt with slothfully on this score, and bring them up, but my hope is that in trying to give what help and what encouragement and what courage we can to the generations our junior, we will also manage to give them some sense of how all this happened.

LEACH: And hope also that many of this new generation also become politicians.

OPPENHEIMER: Yes; of course, I don't want to say that error is only recognised in the sciences. It seems to me that great statesmen have always been wonderfully aware of it and that the greatest have been aware of the fact that their decisions had every chance of being quite wrong. I don't think it was from studying physics that Hamlet's indecision came so... it would be very foolish to claim a monopoly for science but it is - it's probably the only human activity which really doesn't do anything else than throw out mistakes.

LEACH: I suppose really the key word to this is anti-dogma.

OPPENHEIMER: Well that's not right either because without the dogma there would be no error to correct. It's just against - against taking for granted the fact that there's nothing new in the world.